

**Final Technical Report**

**Grant: NAG5-1858**

**"Guaranteed Time Observations Support for  
Goddard High Resolution Spectrograph (GHRS) on HST"**

**Edward Beaver, Principal Investigator**

**Grant Period: Nov. 15, 1992 – Nov. 14, 1998**

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# **Final Technical Report**

## **Guaranteed Time Observations Support for Goddard High Resolution Spectrograph (GHRS) on HST**

**NAG5-1858**

**January 15, 1992 -- November 14, 1998**

**Ed Beaver, P.I.**

**University of California, San Diego  
9500 Gilman Drive, La Jolla CA 92093-0111**

### **1. Introduction**

We assemble this final grant report by combining our previously submitted progress reports with the last years's progress report. Section 2 is the progress report for the June 1, 1991 to Nov. 14, 1995 period. Section 4 is the progress report for the Nov.14, 1996 to Dec.31,1996 period. Section 5 is the progress report for the Nov.14 to Aug. 31,1997 period. Section 5 is the new progress report for the Sept. 15, 1997 to Nov. 14, 1998 final period. Section 3 is a summary of our spare detector high voltage transient tests activity in 1992 in support of the renewed safe operation of the GHRS HST D1 detector.

Note that we have left the format of each progress report the same as originally sent out. The slight differences in format presentation are thus intended.

### **2. June 1, 1991 to November 14, 1995 Submitted Progress Report**

#### **Technical Progress Report**

## **Guaranteed Time Observations Support for Goddard High Resolution Spectrograph (GHRS) on HST**

**NAG5-1858**

**June 1, 1991 -- November 14, 1995**

**Ed Beaver, P.I.**

**University of California, San Diego**

## I. Overall Progress

### A. Results Obtained During the Reporting Period

#### 1. GTO Observations

The goals of the GTO effort are for investigations defined in previous years by the IDT to be carried out as HST observations and for the results to be communicated to the scientific community and to the public. The following is a listing of GHRS GTO observations in the report period.

Scheduled and completed, with acceptable data:

Yr.day	Prop	Cy	Old #	Title	Target
91.194	1190	1	1190	FUV Em Line profiles, W Serpentis Binaries	W Ser (1/1)
92.257	1191	2	1191	Phys Cond, Low z Abs Line Sys in QSOs	PKS2135-14 (1/3)*
94.163	5177	4	1191	Phys Cond, Low z Abs Line Sys in QSOs	PG1630+337 (2/3)
95.083	5698	4	1191	Phys Cond, Low z Abs Line Sys in QSOs	PG1630+337 (2/3)
95.071	6237	5	1191	Phys Cond, Low z Abs Line Sys in QSOs	PG0935 (3/3)
92.007	1192	1	1192	UV Emission Line Profiles, QSOs & AGN	OX169 (1/1)
91.338	1193	1	1193	Ly $\alpha$ Region of QSOs w Strong Absorp Lines	3C286 (1/3)
91.338	1193	1	1193	Ly $\alpha$ Region of QSOs w Strong Absorp Lines	PKS1229-02 (2/3)
92.359	3939	2	1193	Ly $\alpha$ Region of QSOs w Strong Absorp Lines	PKS1229-02 (2/3)
94.094	5176	4	1193	Ly $\alpha$ Region of QSOs w Strong Absorp Lines	PKS1229-02 Im (2/3)
91.339	1193	1	1193	Ly $\alpha$ Region of QSOs w Strong Absorp Lines	3C196 (3/3)
92.270	3939	2	1193	Ly $\alpha$ Region of QSOs w Strong Absorp Lines	3C196 (3/3)
94.083	5176	4	1193	Ly $\alpha$ Region of QSOs w Strong Absorp Lines	3C196 Image (3/3)

\*Note: the (1/3) indicates this is the first of 3 targets in this program.

#### 2. Publications (including partial support)

##### a) Papers Published or In Press

Rosenblatt, E. I., Beaver, E. A., Cohen, R. D., Linsky, J. B., and Lyons, R. W. 1991, "Cerenkov Background Radiation in Imaging Detectors", in *SPIE Electron Image Tubes and Image Intensifiers*, ed. Csorba, (Bellingham, WA) 1449, 72

Hutchings, J. B., Bruhweiler, F., Boggess, A., Heap, S R., Ebbets, D., Beaver, E., Rosenblatt, E., Truong, K. Q., Perez, M., Westmacott, R. 1991, "First Results from the Goddard High-Resolution Spectrograph: Ultraviolet Spectra of A Starburst Knot in NGC 1068", *Ap. J.*, 377, L25.

Beaver, E. A., Baity, W. A., Brandt, J. C., Ebbets, D. C., Garner, H., Heap, S. R., Lindler, D. J., Linsky, J. B., Lyons, R. W., Rosenblatt, E. I. 1992, "Orbital Performance of the Goddard High Resolution Spectrograph Digicon Detectors on the Hubble Space Telescope", *Photoelectronic Image Devices* 1991, ed. B. L. Morgan, 65.

Beaver, E. A., Cohen, R. D., Diplas, A., Garner, H., Heap, S. R., Loveland, M., and Robinson, R. D. 1993, "Calibration of GHRS Burst Noise Rejection Techniques", *Calibrating Hubble Space Telescope*, (Proceedings of a Workshop held at ST ScI, Nov. 1993), eds. J. C. Blades and S. J. Osmer, [Baltimore: Space Telescope Science Institute], 304.

- Linsky, J. L., Brown, A., Gayley, K., Diplas, A., Savage, B. D., Ayres, T. R., Landsman, W., Shore, S. N., and Heap, S. R. 1993, "GHRS Observations of the Local Interstellar Medium and the Deuterium/Hydrogen Ratio Along the Line of Sight Towards Capella", *Ap. J.*, **402**, 694.
- Brandt, J. C., Heap, S. R., Beaver, E. A., Boggess, A., Carpenter, K. G., Ebbets, D. C., Hutchings, J. B., Jura, M., Leckrone, D. S., Linsky, J. L., Maran, S. P., Savage, B. D., Smith, A. M., Trafton, L. M., Walter, F. M., Weymann, R. J., Snow, M., Randall, C. E., Lindler, D. J., Shore, S. N., Morris, S. L., Gilliland, R. L., Lu, L., and Robinson, R. D. 1993, "Observations of 3C 273 with the Goddard High Resolution Spectrograph on the Hubble Space Telescope", *AJ*, **105**, 831.
- Brandt, J. C., Heap, S. R., Beaver, E. A., Boggess, A., Carpenter, K. G., Ebbets, D. C., Hutchings, J. B., Jura, M., Leckrone, D. S., Linsky, J. L., Maran, S. P., Savage, B. D., Smith, A. M., Trafton, L. M., Walter, F. M., Weymann, R. J., Ake, T. B., Bruhweiler, F., Cardelli, J. A., Lindler, D. J., Malumuth, E., Randall, C. E., Robinson, R., Shore, S. N., Wahlgren, G. 1994, "The Goddard High Resolution Spectrograph: Instrument, Goals, and Science Results", *P.A.S.P.*, **106**, 890.
- Heap, S. R., Brandt, J. C., Randall, C. E., Carpenter, K. G., Leckrone, D. S., Maran, S. P., Smith, A. M., Beaver, E. A., Boggess, A., Ebbets, D. C., Garner, H. W., Hutchings, J. B., and Jura, M., *et al.* "The Goddard High Resolution Spectrograph: In-Orbit Performance", 1995, *P.A.S.P.*, **107**, 871
- Diplas, A., Beaver, E. A., Blanco, P. R. Piña, R. K. and Puetter, R. C., 1994, "Application of the Pixon Based Restoration to HST Spectra and Comparison to the Richardson-Lucy and Jansson Algorithms: Restoration of Absorption Lines", in *"The Restoration of HST Images and Spectra II"*, eds. R. J. Hanish and R.L. White (Baltimore, Md.: Space Telescope Institute Publications), 272.
- Diplas, A. and Savage, B. D., 1994 "An IUE Survey of Interstellar H I Ly  $\alpha$  Absorption. I. Column Densities", *Ap. J.* **427**, 274.
- Diplas, A. and Savage, B. D., 1994 "An IUE Survey of Interstellar H I Ly  $\alpha$  Absorption. II. Interpretations", *Ap. J. Suppl.* **93**, 211.
- Cohen, R. D., Barlow, T. A., Beaver, E. A., Junkkarinen, V. T., Lyons, R. W., Smith, H. E., 1994, "Conditions in the z=0.692 Absorber Towards 3CR 286", *Ap. J.*, 1994, **421**, 453-457.
- Burbidge, E. M., Beaver, E. A., Barlow, T. A., Cohen, R. D., Diplas, A., Hamann, F., Junkkarinen, V. T., and Lyons, R. W. 1995, "Recent Results from the UCSD FOS and GHRS Team", Conference Proceedings, *ESO Workshop on QSO Absorption Lines*, ed. Georges Meylan (Germany : ESO), 201.
- Weiland, J. L., Shore, S. N., Beaver, E. A., Lyons, R. W., and Rosenblatt, E. I., 1995 "Goddard High-Resolution Spectrograph Observations of the Interacting Binary System W Serpentis", *Ap. J.*, **447**, 401.
- Linsky, J. L., Diplas, A., Wood, B., Brown, A., Ayres, T., and Savage, B. D. 1994, "Deuterium and the Local Interstellar Medium Properties for the Procyon and Capella Lines of Sight", *Ap. J.*, **451**, 335.

#### b) Conference Proceedings

- Diplas, A., Tripp, T. M., Beaver, E. A., 1993 "Observations of High Velocity Gas with HST/FOS and IUE," presented at the *ST ScI Halos Workshop*, Baltimore, MD.
- Diplas, A., Beaver, E. A., Blanco, P. R., 1993 "Application of the Pixon Based Restoration to HST Spectra and Comparison to the Richardson-Lucy and Jansson Algorithms--Restoration of Absorption Lines", presented at the *HST Image Restoration Workshop*, Baltimore, Maryland.
- Linsky, J. L., Diplas, A., Savage, B. D., Andrusis, C., and Brown, A. 1993, "Deuterium in the Local Interstellar medium", in *"Frontiers of Space and Ground-based Astronomy"*, ESTEC Workshop, Noordwijk, Netherlands.

Linsky, J. L., Diplas, A., Ayres, T., Wood, B., Brown, A. and Savage, B. D. 1994, "Hubble Observations of D/H in the Local ISM and Consequences for Cosmology", in *"Light Element Abundances"*, ESO/EIPC Workshop, Elba, Italy.

### c) Abstracts and Invited Talks

#### Abstracts for 179th AAS Meeting, Atlanta, Georgia, January 1992

Lyons, R. W., Beaver, E. A., Rosenblatt, E. I., Weiland, J. L., "Spectroscopic Observations of the W Serpentis Binary System with the HST High Resolution Spectrograph", *B.A.A.S.*, **23**, 1415 (1991).

#### Abstracts for 180th AAS Meeting, Columbus, Ohio, June 1992

Beaver, E. A., Cohen, R. D., Junkkarinen, V. T., "Damped Lyman Alpha Absorption in 3CR 286", *B.A.A.S.*, **24**, 806 (1992).

#### Abstracts for 182nd AAS Meeting, Berkeley, California, June 1993

Diplas, A., Beaver, E. A., Cohen, R. D., Junkkarinen, V. T., and Lyons, R. W., "HST/FOS UV and Optical Observations of the QSO OX 169", *B.A.A.S.* **25**, 792, (1993).

#### Abstracts for the 183rd AAS Meeting, Washington, D.C., January 1994

Linsky, J. L., Diplas, A., Ayres, T., Wood, B., and Brown, A. 1994, "A Reanalysis of the Interstellar Medium Along the Capella Line of Sight", *B.A.A.S.*, **25**, 1464.

#### Abstracts for the 184th AAS Meeting, Minneapolis, MN, May-June 1994

Diplas, A., Cohen, R. D., Barlow, T. A., Beaver, E. A., Junkkarinen, V. T., and Lyons, R. W., "HST/FOS UV and WFPC II Observations of 3CR 196", *B.A.A.S.*, 1994, **26**, No. 2, 959.

#### Abstracts for the 185th AAS Meeting, Tucson, AZ, January 1995

Beaver, E. A., Burbidge, E. M., Cohen, R. D., Diplas, A., Junkkarinen, V. T., Lyons, R. W., and Loveland, M., 1994 "Looking for the Sources of Damped Ly  $\alpha$  Absorption Lines in QSO Spectra", *B.A.A.S.*, **26**, 1331.

Cohen, R. D., Beaver, E. A., Diplas, A., Junkkarinen, V. T., and Lyons, R. W. 1994, "Observations of the 21 cm Absorber PKS 1229-021", *B.A.A.S.*, **26**, 1330.

### 3. Public Outreach

Informing the public is also a part of our mission. GHRS GTO team members regularly give public information lectures. W. Baity is the host of and science consultant to a semi-monthly UCSD-TV series on astronomy and space science. In the area of public information, we include the following:

- a) GHRS GTO team members at UCSD gave public information lectures and furnished a display for the ASP "Universe '93" meeting in San Diego in July 1993.
- b) GHRS team members at UCSD have maintained informative pages on the World Wide Web since June, 1994. to communicate our results to scientific colleagues and to the public.

- c) Two team members (Cohen and Baity) addressed a 300- teacher training workshop at UCSD in June 1994.
- d) Ross Cohen, presented "HST Results: Update" in the Astronomy Public Lecture Series, Reuben H. Fleet Space Theater, San Diego on 4/26/95.
- e) W. Baity gave a public lecture on "How HST Results are Changing our View of the Universe" to two audiences at San Diego's Fleet Space Theater in November, 1995.

## B. Scientific Significance of Selected GTO Results

### 1. Results from Investigation 1190: the W Serpentis Interacting Binary System

Spectroscopic observations of the interacting binary system W Serpentis were made at two different orbital phases with the GHRS. Differences in Si IV  $\lambda\lambda$  1393, 1403 emission-line strengths and profile shapes observed between the two phases suggest that a hot spot exists where the giant stellar companion has transferred mass to an accretion disk surrounding the mass-gaining component. Moreover, strong absorption features superposed on the Si IV emission lines indicate that the accretion disk is geometrically and optically thick. These absorption features set constraints on models of the physical conditions of the disk.

### 2. Results from Investigation 1193: Ly $\alpha$ Region of 3 QSOs with Strong Absorption Lines

The damped Ly  $\alpha$  systems at high redshifts have been suggested as the progenitors of normal galaxies. At moderate redshifts we can study these objects comprehensively with the HST. We have observed three quasars with 21 cm absorption and redshifts between 0.4 and 0.7 with the FOS and Wide Field Camera (WFC). As described below, the three objects show significantly different properties, rather than showing the similarities we might have suspected from their radio properties.

Observation of Ly  $\alpha$  combined with 21 cm absorption yields the spin temperature,  $T_s$ , which may be indicative of the rate of energy input into the ISM. One goal of this work is to determine the rate of evolution of  $T_s$ . In 3CR286,  $z_a=0.692$ , we have found a spin temperature much higher than in the Galaxy and as high as in high-redshift objects. By comparing the column densities of metals measured in the optical with N(H I) measured in the UV, we have shown that the absolute abundances of Fe, Mg, and Ca in this object are very low. This is surprising, because we are seeing the ISM of this galaxy at a look-back time approximately equal to the age of the sun. Our WFC images do not clearly reveal the absorbing galaxy, suggesting that it may be a low surface brightness object and not a normal spiral galaxy.

In 3CR196,  $z_a=0.437$ , we have detected the probable site of the 21 cm absorption which occurs against the extended radio structure. It appears to be a normal barred spiral galaxy. The interpretation of the spectrum is complicated, but it appears the Ly  $\alpha$  column density is high towards the optical QSO, several kiloparsecs away from the site of the 21 cm absorption. This suggests that the absorber is a normal spiral with a typical extended H I disk, and not a dwarf or a disturbed galaxy. In our spectrum of 3CR 196, we were also able to study an absorption system with approximately the same redshift as the emission lines. This absorption region appears to only partially cover the continuum source. We have found that the ionization is high, similar to that in Broad-Absorption-Line QSOs (BALQSOs). If the density is like the assumed density in BALQSOs, then the absorption region is close to the nuclear continuum source but outside the broad-line region.

The third object, PKS 1229-021, is being analyzed now. In this object, the absorber is a relatively low luminosity galaxy with a high Ly  $\alpha$  column density and low spin temperature. However, the morphology of the absorber is not obvious. We have detected [O II] emission from the nearby galaxies using observations with the Keck Telescope. From this we derive a star-formation rate of only a few solar masses per year. We can use this measurement (together with future work at high redshift) to derive the star formation history of the objects responsible for the damped Ly  $\alpha$  and 21 cm systems.

## II. Current Problems

None *per se*, but in order to complete detailed analysis of GHRS GTO data, we will likely need a no-cost extension beyond the end of the GTO support period in December 1996.

## III. Plans for the Next Year of Support

The GHRS GTO at UCSD team has successfully completed the observation phase of their GTO investigations and for the next year will perform analyses of the observations listed in the first section above and complete work on previously obtained data. The HST has been performing up to its original design specifications, which is a testimonial to all those who worked hard on this project and its maintenance and repair.

### 3. GHRS Spare Detector High Voltage Transient Confidence Tests at UCSD

In 1992 UCSD was asked by NASA to perform high voltage transient tests on the spare GHRS D2 detector. These tests were necessitated by the intermittent failure of the flight GHRS side 1 low voltage power supply, which in turn caused high voltage transients on the D1 detector. Around July 1991, the high voltage operation of the D1 Detector was discontinued until a plan for safe operation was developed.

During the GHRS Detector phase, rapid high voltage changes caused damage to the detectors. The detector failure mode was an elevated (100 times higher than spec) detector background level due to light discharges in the Digicon high voltage front end ceramic spacer cylinder. Even though design safeguards were built into later flight designs (a chrome oxide surface was added to the ceramic spacer), NASA needed this additional ground test simulation data in order to characterize the performance of the flight detector after being subjected to a series of high voltage transients on a GHRS flight detector.

After the D2 spare detector was transferred to non flight status, UCSD personally transported the D2 detector from Ball Aerospace, Boulder by ground transportation (ie rental car) to our UCSD test lab. UCSD then converted the FOS vacuum chamber and data acquisition test stand to acquire data from the GHRS D2 detector head assembly. In addition a 386 IBM computer with new software was added to be a real time interface to the GHRS high voltage power supply so that the high voltage power supply could be sequenced on and off in a preset pattern.

After each high voltage pattern, three measurements were made: 1. a dark count to measure any background changes, 2. a detector faceplate mask edge response scan to measure any resolution changes, and 3. a count rate measurement on a stable ultraviolet light source to see if the detector quantum efficiency changed. These measurements are summarized in Table 1. We started out on 10/2/92 with the potentially least damaging high voltage transient sequence of a step high voltage off (from ~22 kilovolt to 0 volts) for 5 seconds then a step turn on (0 volts to 22 kilovolts). Since this was only 1 cycle, the background, edge response, and standard lamp were measured immediately after this sequence. The high voltage transient tests were finished on 10/28/92 with the sequence of 100 cycles of a 30 second on/off high voltage pattern. Note that nominal D2 detector performance before these transient tests were the following: 1. background = 0.001 cts/sec/diode, 2. Edge full width half max = 50 microns, and 3. UV response = 1.00.

A statistical analysis of the data from the sequence of high voltage transient test patterns shown in table 1 shows no significant changes in the D2 detector performance. Thus it has been demonstrated that the flight GHRS Detector can safely survive a reasonable series of high voltage transients. GHRS NASA Goddard engineer Frank Rebar requested UCSD to write up this high voltage test simulation into a report, so that he could use it to support the high voltage operation of the D1 detector on the HST. We delivered this written report to Mr. Rebar around December 1992. Shortly thereafter the D1 detector was successfully brought back to high voltage operation for the rest of the GHRS mission lifetime on the HST.

TABLE 1: HIGH VOLTAGE TRANSIENT DATA FOR SPARE D2 DETECTOR TESTS

DATE	TIME OFF (SEC)	CYCLE (#)	BACKGROUND ( $10^{-3}$ C/D/S)		EDGE FWHM (MICRONS)		UV RESPONSE (NORMALIZED)	
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
10/2/92	5	1	0.55	0.91	49.7	50.6	1.000	0.869
10/7/92	10	1	1.27	0.91	48.8	46.2	1.005	0.953
10/12/92	30	1	1.82	1.82	48	49.7	1.084	0.999
10/16/92	300	1	0.36	1.45	44.3	49.4	1.033	0.921
10/16/92	5	10	0.91	0.91	48.8	49.2	1.011	0.910
10/19/92	10	10	0.55	0.91	47.4	44.3	1.041	0.964
10/19/92	30	10	0.73	0.91	44.8	48.8	1.013	0.952
10/23/92	300	10	1.09	1.82	48.6	46.9	1.074	1.033
10/26/92	30	100	0.91	0.55	50.9	47.4	1.061	0.991
10/28/92	30	100	1.09	0.73	48	52	1.050	1.035
AVERAGE OF COLUMN ENTRIES			1.01	1.09	47.93	48.45	1.037	0.963
3 SIGMA ERROR OF ENTRIES			1.29	1.29	TBD	TBD	0.019	0.019

#### 4. Nov. 14, 1996 to Dec. 31, 1996 Submitted Technical Progress Report

### Technical Progress Report

Guaranteed Time Observations Support for  
Goddard High Resolution Spectrograph (GHRS) on HST

NAG5-1858



November 14, 1995 -- December 31, 1996

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## **I. Overall Progress**

### **A. Results Obtained During the Reporting Period**

#### **1. GTO Observations**

The goals of the GTO effort are for investigations defined in previous years by the IDT to be carried out as HST observations and for the results to be communicated to the scientific community and to the public.

#### **2. Publications (including partial support)**

##### **a) Papers Published or In Press**

Cohen, R. D., Beaver, E. A., DiPas, A., Junkkarinen, V. T., Barlow, T. A. and Lyons, R. W., 1996 "A 21cm Absorber Identified with a Spiral Galaxy: HST/FOS and WFPC 2 Observations of 3CR 196", *Ap. J.*, 456, 132.

##### **b) Conference Proceedings**

None.

##### **c) Abstracts and Invited Talks**

**Abstracts for 187th AAS Meeting, San Antonio, Texas, January 1996**

Cohen, R. D., Beaver, E. A., Hamann, F. W., Junkkarinen, V. T., Lyons, R. W. 1996, "A Search for He I Absorption in the Ly alpha Forest Clouds", *BAAS*, 27, 1412, 1995.

Hamann, F., Beaver, E. A., Cohen, R. D., Junkkarinen, V. T., Lyons, R. and Barlow, T. A. 1996, "Metal Abundances and Ionization in QSO Intrinsic Absorbers", *BAAS*, 27, 1412.

Burbidge, E. M., Beaver, E. A., Cohen, R. D., Hamann, F., Junkkarinen, V. T., Lyons, R. W., and Zuo, L. 1996 "Hubble Space Telescope Images and Spectra of Objects Around an Optically Violent Variable QSO", *BAAS* 27, 1414.

#### **3. Public Outreach**

Informing the public is also a part of our mission. GHRS GTO team members regularly give public information lectures. W. Baity is the host of and science consultant to a semi-monthly UCSD-TV series on astronomy and space science. In the area of public information, we include the following:

- a) GHRS GTO team members at UCSD gave public information lectures at the Fleet Space Theater, San Diego's planetarium and at various public and school events.

- b) GHRS team members at UCSD have maintained informative pages on the World Wide Web since June, 1994.

## B. Scientific Significance of Selected GTO Results

**PKS 1229-021:** We completed the model fits to the UV spectrum of this 21 cm absorber. The best estimate the column density places this system clearly within the damped Ly $\alpha$  sample. We performed a careful extraction of the optical spectrum of the nearby galaxy in the spatial region which corresponds to the location of the galaxy detected in the WFPC2 image. The only detected feature is [O II] in emission at the redshift of the absorption system. The deduced star formation rate based on the [O II] line is 2 solar masses per year. All of the measurements have been completed, as has most of the paper, which will be submitted shortly.

**PG1630+377:** We made preliminary measurements of all lines in the spectrum of the bright QSO PG1630+377 to measure and set limits on the He I/H I ratio. We found one possible line of He I  $\lambda$ 584 associated with a Lyman limit, and we have set limits on the He I/H I ratio in the forest. In the Lyman limit system, we derive  $N(\text{H I})/N(\text{He I}) \approx 100$ , assuming that the absorption line is a single component. We used photoionization models (produced using CLOUDY) and the best published estimate of the metagalactic UV background to derive the properties of the cloud producing the He I absorption. In order to match the derived abundance ratio, a very high ionization parameter is required, with a correspondingly low density and H I fraction, leading to an unrealistically large cloud. More realistic cloud sizes require that the He I column could be considerably larger than measured (as would be the case if the He I absorption line is a blend of a number of unresolved lines). Alternatively, a harder power law continuum could require a lower ionization parameter and clouds of only 30 kpc diameter.

**PG0935+417:** Our analysis indicates that measurement of lines of molecular H in this spectrum is not possible, due to contamination by other lines in that system, the Ly $\alpha$  forest, and lines in an absorption system at the emission redshift which we have detected in the UV spectrum. We have acquired and reduced high resolution optical data from the Keck telescope that we can use with absorption lines in the UV spectrum to study both the damped Ly $\alpha$  system in which we had hoped to detect molecular H and the system at the emission redshift. The signal-to-noise of these optical data is too low, and we require additional integration time, for which we have been allocated telescope time in January, 1997.

## II. Current Problems

None *per se*, but in order to complete detailed analysis of GHRS GTO data, we will need a no-cost extension beyond the end of the GTO support period in December 1996.

## III. Plans for the Next Year of Support

The GHRS GTO at UCSD team has successfully completed the observation phase of their GTO investigations and for the next year will perform analyses of the observations listed in the first section above and complete work on previously obtained data. The HST has been performing up to its original design specifications, which is a testimonial to all those who worked hard on this project and its maintenance and repair.

# 5. November 14, 1996 to August 31, 1997 Submitted Technical Progress Report

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The goals of the GTO effort are for investigations defined in previous years by the IDT to be carried out as HST observations and for the results to be communicated to the scientific community and to the public.

##### **2. Publications**

###### **a) Papers Published or In Press or in draft**

Brandt, J. C., Heap S. R., Beaver E. A., et. al., 1997, "Observations of 3C 273 with the Goddard High Resolution Spectrograph On The Hubble Space Telescope", *The Astronomical Journal*, 114, 554-564.

Hamann, Fred, Beaver, E. A., Cohen, R. D., Junkkarinen, V. T., Lyons, R. W., Burbidge E. M., 1997, "The Nature and Origin of  $z_s \approx z_e$ ", *Ap. J.*, in press

Cohen, R. D., Beaver, E. A., Diplaz, Athanassios, Junkkarinen, V., and Lyons, R. W., "HST and Keck Observations of PKS 1229-021 - The Star Formation Rate at  $z \approx 3.95$ ", in draft form to be submitted to *Ap. J.* shortly.

###### **b) Conference Proceedings**

Hamann, Fred, Barlow T., Cohen, R. D., Junkkarinen, V., 1997, "High-Velocity Narrow-Line Absorbers in QSO's", to appear in "Mass Ejection from AGN," eds. R. Wemmann, I. Shlosman, N. Arav, ASP Conf. Series, in press

##### **3. Public Outreach**

Informing the public is also a part of our mission. GHRS GTO team members regularly give public information lectures. W. Baity is the host of and science consultant to a semi-monthly UCSD-TV series on astronomy and space science. In the area of public information, we include the following:

a) GHRS GTO team members at UCSD gave public information lectures at the Fleet Space Theater, San Diego's planetarium and at various public and school events.

b) GHRS team members at UCSD have maintained informative pages on the World Wide Web since June, 1994.

## B. Scientific Significance of Selected GTO Results

**PKS2135-147:** We use new UV and optical spectra and an archival HST-WFPC2 image to study the  $z_a \sim z_e$  absorber in the  $z_e = 0.20$  QSO PKS 2135-147. The UV spectra show strong  $z_a \sim z_e$  absorption lines of C IV, N V, O VI, Ly-alpha and Ly-beta. The  $z_a \sim z_e$  line profiles are resolved, with deconvolved FWHM of 270 to 450 km/s. Lower limits on the total column densities are of order  $10^{15} \text{ cm}^{-2}$  for all ions. If the absorber is photoionized by the QSO and the derived relative columns in C IV and H I are roughly correct, then the metallicity must be at least solar. The location of the  $z_a \sim z_e$  absorber remains uncertain. Two  $\sim L_*$  galaxies in a small cluster centered on PKS 2135-147 lie within  $36 h^{-1}$  kpc projected distance and have redshifts consistent with causing or contributing to the  $z_a \sim z_e$  lines. The extensive halo of the QSO's host galaxy could also contribute. Calculations show that the QSO is bright enough to photoionize gas up to O VI in the low-density halos of the host and nearby cluster galaxies. Nonetheless, there is indirect evidence for absorption much nearer the QSO, namely (1) the derived high (albeit uncertain) metallicity, (2) the relatively strong N V absorption lines, which might be caused by a higher nitrogen abundance in the metal-rich gas, and (3) strong, lobe-dominated steep-spectrum radio emission, which is known to correlate with a much higher incidence of (probably intrinsic)  $z_a \sim z_e$  lines. We propose that the CIV/NV/OVI line ratios can be used as a general diagnostic of intrinsic versus intervening absorption, as long as the line saturation effects are understood.

A postscript file version of this paper on our GHRS GTO observation of PKS2135-147 is located on the World Wide Web at <http://xxx.lanl.gov/ps/astro-ph/9705240>.

**Damped Lyman Alpha Systems:** We have continued our studies of low redshift damped Lyman alpha systems. The purpose of this program is to study the evolution galaxies from high redshifts to the present day. While ground based observations are sufficient at high redshifts, HST observations are required to measure features in the UV at times closer to the present. For this program we obtained GTO imaging and spectroscopic observations of four quasars. Observations of two have already been published. In this period, we made use of the unique capabilities of the Keck telescope to acquire high resolution, high signal to noise observations of metal lines in the optical region of our target quasars.

We wish to understand the evolution of the abundance of the elements at low redshift. This is complicated by the absorption of some elements onto dust grains. However, the combination of HST and Keck observations allows us to both measure absolute abundances of the elements and to determine whether the abundances show the signature of metallicity variations of dust absorption. We have obtained complete or partial high resolution data sets on PG 0935+417, PKS 1229-021, and 3CR 286, including lines of Zn II, Cr II, Mn II, Ti II, and Ca II and begun detailed fits of the line profiles to measure the abundances.

PG 0935+417 also has an absorption system at the emission redshift, and a "mini" broad absorption line system more than 50,000 km/s blueward of the emission redshift. Fortunately, lines of these systems fall in both our HST and ground based spectra. Modeling of the physical conditions in both these systems using both data sets has begun.

**PKS 1229-021:** During this period of performance we successfully acquired Keck hi-res data (6 km/s) on this object and modeled the absorption line profiles of the optical spectrum in order to determine abundances. All of the measurements when combined with our HST data indicate a Mn abundance down by a factor of 10 with respect to solar, despite a look back time of only  $3.4 \times 10^9$  years. The Ti/Mn ratio indicates that this is not due to depletion of metals onto dust grains. Our paper on PKS1229-021 entitled *HST and Keck Observations of PKS 1229-021 - The Star Formation Rate at  $z=0.395$*  will be submitted to *ApJ* shortly.

**PG1630+377:** We made preliminary measurements of all lines in the spectrum of the bright QSO PG1630+377 to measure and set limits on the He I/H I ratio. We found one possible line of He I  $\lambda 584$  associated with a Lyman limit, and we have set limits on the He I/H I ratio in the forest. In the Lyman limit system, we derive  $N(\text{H I})/N(\text{He I}) \approx 100$ , assuming that the absorption line is a single component. We used photoionization models (produced using CLOUDY) and the best published estimate of the metagalactic UV background to derive the properties of the cloud producing the He I absorption. In order to match the derived

abundance ratio, a very high ionization parameter is required, with a correspondingly low density and H I fraction, leading to an unrealistically large cloud. More realistic cloud sizes require that the He I column could be considerably larger than measured (as would be the case if the He I absorption line is a blend of a number of unresolved lines). Alternatively, a harder power law continuum could require a lower ionization parameter and clouds of only 30 kpc diameter.

PG0935+417: During this period of performance we acquired and reduced high resolution optical data from the Keck telescope that we can use with absorption lines in the UV spectrum to study both the damped Ly $\alpha$  system in which we had hoped to detect molecular H and the system at the emission redshift. Unfortunately the signal-to-noise of some of the regions of the optical data is too low due to cloudy weather problems during the observation, and we require additional integration time. Fortunately we have been allocated Keck telescope time for PG0935+417 on December 24, 1997.

## **II. Current Problems**

None *per se*, but in order to complete detailed analysis of GHRS GTO data, we will need a no-cost extension beyond the end of the GTO support period of November 15, 1997.

## **III. Plans for the Next Year of Support**

The GHRS GTO at UCSD team has successfully completed the observation phase of their GTO investigations and for the next year will complete work on previously obtained data.

# **6. September 15, 1997 to November 14, 1998 Technical Progress Report (NEW)**

## **Technical Progress Report**

### **Guaranteed Time Observations Support for Goddard High Resolution Spectrograph (GHRS) on HST**

**NAG5-1858**

**September 15, 1997 -- November 14, 1998**

**Ed Beaver, P.I.**

**University of California, San Diego  
9500 Gilman Drive, La Jolla CA 92093-0111**

## **I. Overall Progress**

### **A. Results Obtained During the Reporting Period**

## 1. GTO Observations

No Observations this period.

## 2. Publications

### a) Papers Published, In Press, in draft, or in preparation

Cohen, R. D., Beaver, E. A., DiPas, Athanassios, Junkkarinen, V., and Lyons, R. W., "HST and Keck Observations of PKS 1229-021 - The Star Formation Rate at  $z=0.395$ ", in draft form to be submitted to *Ap. J.*

Cohen, R. D., Beaver, E. A., Hamann, F., Junkkarinen, V., Lyons, R., "A search for He I Absorption in Ly Forest Clouds in Spectra of QSO PG 1630+377", in preparation form, to be submitted to a workshop.

Hamann, F., Barlow, T., Beaver, E., Cohen, R. D., Junkkarinen, V., and Burbidge, E. M., "High-Velocity Narrow-Line Absorbers in QSO's", in preparation form, to be submitted to *Ap. J.*

Junkkarinen, Beaver, Cohen and Smith, "Metal abundances in the Low-Redshift Damped Lyman alpha Absorption System in 3CR 286", in preparation form, to be submitted to *ApJ*.

### b) Conference Proceedings

Cohen, R. D., Beaver, E. A., Junkkarinen, V. T., Lyons, R. W., Smith, H. E., "High Resolution Spectra of Low Redshift Damped Ly $\alpha$  Absorption Systems" 1998, *BAAS*, 30, 889.

## B. Scientific Significance of Selected GTO Results

**Damped Lyman Alpha Systems:** Our analysis of spectra of low redshift damped Lyman alpha systems continued. We are combining high resolution optical observations of metal absorption lines obtained at Keck Observatory with observations of Lyman alpha obtained with HST. This combination allows us to determine absolute metal abundances of important ionic species, including some with very low abundances and weak lines.

**3C286:** Our Keck optical spectra of 3C286 are completely analyzed. The results are particularly accurate because of the simple velocity structure in this system. The simple velocity structure also allows a measurement of the diagnostically important Mg abundance. Results are as follows for logarithmic abundances relative to solar abundances:

[Mg II/H]=-1.12; [Ti II/H]=-1.54; [Cr II/H]=-1.440; [Mn II/H]=-1.8;  
[Fe II/H]=-1.70; and [Zn II/H]=-1.39.

The debate over the abundances of the damped Lyman alpha systems centers on whether the relative abundances are indicative of absorption onto dust grains, or whether they show an abundance pattern indicative of type II supernova abundances. At first glance, the abundances of the Fe group elements Cr, Fe, and Zn do not appear compatible with either interpretation. The Cr/Zn ratio suggests that little or no dust is present, but in that case the low Fe abundance appears inexplicable. Fe, Zn, and Cr should have the same intrinsic abundance because they should have the same nucleosynthetic history, yet in the absence of dust, Cr appears 80% overabundant with respect to Fe. However, if we use the formalism of Vladilo (1998, *ApJ*, 493, 583), who proposes that the composition of dust grains is the same regardless of the amount of dust, we find that the measured abundances are compatible with a type II abundance pattern on which has been imposed the signature of a small amount of dust depletion. The only exception appears to be Cr, whose abundance is 20% higher relative than expected relative to Fe. This is difficult to explain, but within the scatter measured for

Galactic stars. The derived relative abundances of Mg and Ti abundances are high relative to solar, while the abundance of Mn is low. These results are consistent with predictions of abundances dominated by the output of type II supernovae. This new 3CR 286 work will likely be submitted for publication as "Metal abundances in the Low-Redshift Damped Lyman alpha Absorption System in 3CR 286" by Junkkarinen, Beaver, Cohen and Smith.

PKS 1229-021: At the 192<sup>nd</sup> meeting of the American Astronomical Society we presented a paper entitled "High Resolution Spectra of Low Redshift Damped Ly $\alpha$  Absorption Systems". This paper discussed our most recent scientific interpretations of our PKS1229-021 and 3C286 optical and HST spectra. The abstract for this paper follows-

"We have been able to form a fairly complete picture of the galaxy responsible for the  $z_{\text{d}}=0.395$  absorption line system in PKS 1229-021 by combining Keck HIRES and LRIS spectroscopy with observations taken with the Hubble Space Telescope. The image of the absorber is consistent with the inclined disk of a moderately luminous spiral galaxy. We have not been able to detect the continuum from this galaxy spectroscopically, but our LRIS spectra show emission from (O II  $\lambda 3727$  which can be interpreted to be indicative of star formation at the rate of a few solar masses per year. The HIRES spectra clearly show an "edge-leading" absorption profile. Prochaska and Wolfe have predicted that the velocity of the center of mass of the absorbing galaxy should fall near one edge of the absorption profile if the damped Ly  $\alpha$  systems are due to the rotating disks of spiral galaxies. The [O II] emission velocity is consistent with this, but there is some ambiguity due to the doublet nature of the [O II] emission. Although the absorption lines of the abundant elements are saturated in the components which correspond to the H I absorption, we have been able to measure accurate column densities for Ca II, Ti II and Mn II for comparison with the H I column density determined from low resolution HST/FOS spectra. The abundances are compatible with approximately 0.1 of solar, with little or no dust, but they are also consistent with lines of sight toward  $\xi$  Oph through warm interstellar clouds."

We have added additional new material to our GHRS PKS 1229-021 paper (in draft) concerning the character of the intervening galaxy, based on discussions with Dr. A. Wolf and others. In addition some issues were brought up by readers of our AAS paper that required changes to our draft paper.

PG 0935+417: Our analysis of the spectrum of PG 0935+417 is less advanced. However, we have summed all our high resolution spectra and begun analysis of the absorption features.

PG1630+377 : For a more accurate measurement of line positions, we used the SPECFIT code to deblend all lines in our G140L and H27 HST spectra. Interstellar lines were then used to find absolute line position wavelengths. This additional work was required since we want to determine how many lines in the G160L spectrum are coincident with the HeI (584.334 Å) wavelengths positions associated with the Lyman alpha cloud system lines in the H27 spectrum. Initially using a spreadsheet type of analysis, we initially found that out of the 101 lines in the H27 spectrum and 64 lines the G160L spectrum, eleven G160L lines were found coincident with the HeI wavelengths associated with the Lyman alpha system lines in the H27 spectrum. The issue in these type of measurements is generally whether this positive detection of eleven line coincidences is statistically significant or simply due to random overlaps with Ly $\alpha$  cloud lines in the G160L wavelength range.

In order to look at the statistical significance of this positive detection result, we developed a Monte Carlo code that simulates our line measurements technique. This IDL coded software reads in the H27 Ly $\alpha$  line list and then calculates the HeI line positions associated with the redshift of the H27 lines. The code then generates a simulated G160L random line spectrum with random wavelength positions, but the number of lines equal to that found in the actual G160L spectrum. Next the code finds the HeI H27 Ly $\alpha$  system lines coincident with those in the random G160L lines. This procedure is then looped a thousand times so that a distribution of coincidences is generated.

The result from the Monte Carlo simulation is that a coincidence of eleven lines occurs with a 5.04 percent of the time probability. Generally for these type of analysis, a positive, nonrandom detection is claimed if the process occurs with less than a 3 percent frequency (preferably much less than 3%). Thus the eleven lines that we detect in our G140L spectrum at HeI wavelengths associated with H27 Ly $\alpha$  cloud systems is not quite statistically significant.

We are continuing to try to improve our result by constraining the line selection process by, for example, only looking for coincidences for large equivalent width H27 Ly $\alpha$  cloud system lines only. If we can achieve the 3 percent or less criterion with these additional line constraints, then this work is probably worth submitting a paper to a refereed journal. Otherwise this PG1630 work will make a nice non-referred workshop article.

## 7. Conclusion

We conclude this final report with a complete list of our GHRS papers for this Grant. The papers in draft or preparation should be published over the next several years. We will notify the GHRS Principal Investigator as these papers are published. Although the Principal Investigator of this Grant is now retired from UCSD, he will continue to work with the lead authors of the "to be published papers" until they are published.

### PUBLISHED WORK (Chronological order)

Beaver, E. A., Cohen, R. D., Junkkarinen, V. T., "Damped Lyman Alpha Absorption in 3CR 286" 1992, *BAAS*, **24**, 806.

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#### **Papers in Draft or Preparation**

Cohen, R. D., Beaver, E. A., Junkkarinen, V., and Lyons, R. W., "The Low-Redshift Damped Lyman alpha Absorber Toward PKS 1229-021", in Draft, to be Submitted to *ApJ*.

Cohen, R. D., Beaver, E. A., Hamann, F. W., Junkkarinen, V. T., Lyons, R. W., "A Search for He I Absorption in Lyman alpha Forest Clouds in Spectra of QSOPG 1630+377", in Preparation, likely to be submitted as a workshop publication.

Hamann, F., Barlow, T. A., Cohen, R. D., Junkkarinen, V., Burbidge, E. M., and Beaver, E. A., "High Velocity Narrow-Line Absorbers in QSO's", in Preparation, to be submitted to *ApJ*.